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Ultraluminous X-ray Sources in the Local Universe

"Accretion in Stellar Systems" *CXC*, Cambridge, MA 8–10 August 2018

Importance of Ultraluminous X-ray sources (ULXs)

- Physics at extreme accretion rates:
  super-Eddington accretion, **beaming**

  (see Kaaret+ 2017; King 2008)
- Heating of the universe during the epoch of **reionization**

  (e.g. Fragos+ 2013, Jeon+ 2014, Madau+ 2017)
- **Exotic** objects (e.g. PULXs, HLXs, IMBHs)
  - (e.g. Isreal+ 2017; Earnshaw+ 2016; Fürst+ 2016; Wiktorowicz+ 2015; Bachetti+ 2014; Sutton+ 2012; Madau+ 2001; Colbert+ 1999)
- Progenitors of **gravitational wave** sources

  (see Belczynski+ 2016)

Two ways (and reasons) to study of ULXs

Individual studies

- Compact Objects
- Binary evolution
- Accretion physics

difficulties...

- Measuring CO mass
- Identification of donors
  (e.g. Tao+ 11; Gladstone+ 13)

Statistical studies

- Link with host galaxy properties
- Input for population synthesis
- Formation & binary evolution

difficulties...

- ULXs are rare
- Few host galaxies

Statistical studies of ULX populations

- Connecting the populations with global properties of the host galaxies such as:
  - (Specific) star formation rate
  - Stellar mass
  - Age of stellar populations
  - Metallicity

    Wang+ 16; Plotkin+ 14; Basu-Zych+ 13; Walton+ 11; Swartz+ 11; Mapelli+ 10; Colbert 2004; Kilgard+ 02
- Luminosity functions

  e.g. Wang+ 16; Swartz+ 11; Zezas+ 07

Towards a census of ULX populations and galaxy properties

- A new opportunity with *Chandra Source Catalog 2.0*
- Galaxy sample with:
  - all known galaxies in the local universe (< 200 Mpc)
  - accurate positions, robust distances
- Global properties of galaxies (multi-wavelength data)
  - star formation rate
  - stellar mass
  - metallicity

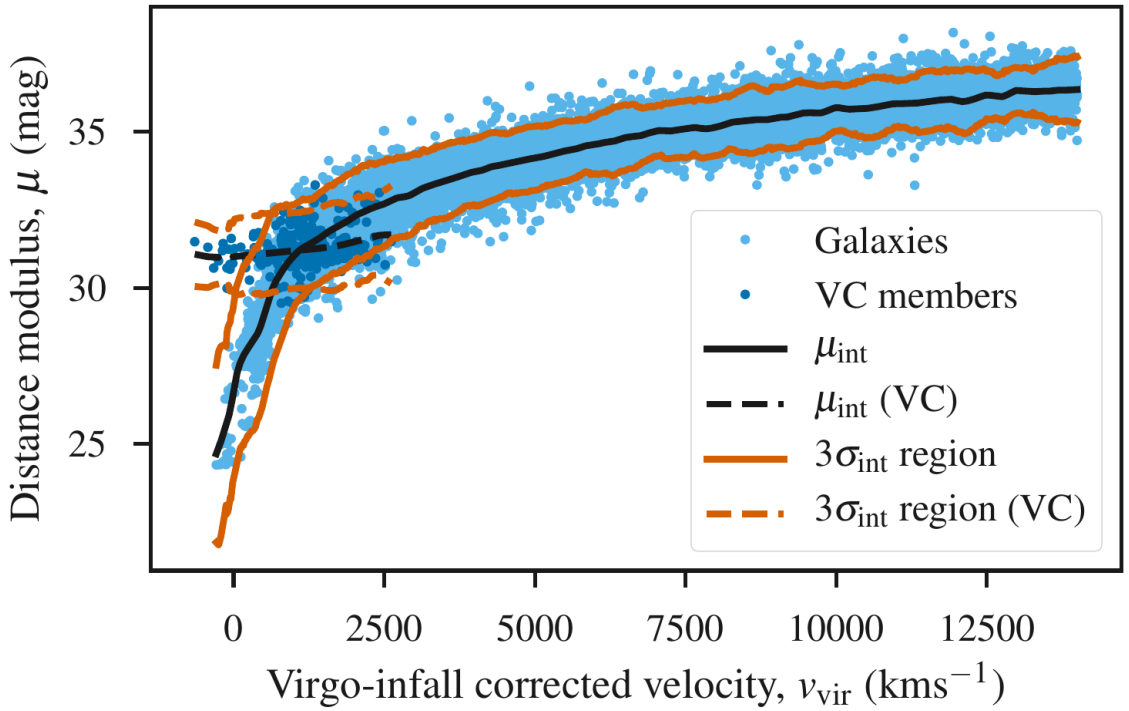
Heraklion Extragalactic CATalogue (*HECATE*): a new local universe catalogue

HyperLEDA galaxies with v < 14000 km/s → ~ 163 000 galaxies

Combination of *NED-D* measurements:

- ~60000 distance measurements from → ~11% of our sample
- ~1200 publications

New z-dependent distances accounting for uncertainties due to **systematic** effects, **peculiar** velocities and local **overdensities**



Multi-wavelength data incorporated in ***HECATE***

All-sky Surveys

- **Revised *IRAS* FSCz Catalogue** (Wang et al. 2014)

  with IRAS, WISE, SDSS, GALEX, 2MASS, Planck, AKARI fluxes

- ***2MASS Extended Source Catalogue*** *(Skrutskie et al. 2006)*
- ***IRAS Revised Bright Galaxy Sample*** *(Sanders et al. 2003)*
- ***2MASS Large Galaxy Atlas*** *(Jarret et al. 2003)*

SDSS footprint

- ***GSWLC*** (Salim et al. 2016)

  SEDs using GALEX, SDSS, WISE

- ***FIREFLY*** population synthesis models (Comparat et al. 2017)
- ***WISE* forced-photometry** (Lang et al. 2016)

...more to follow!

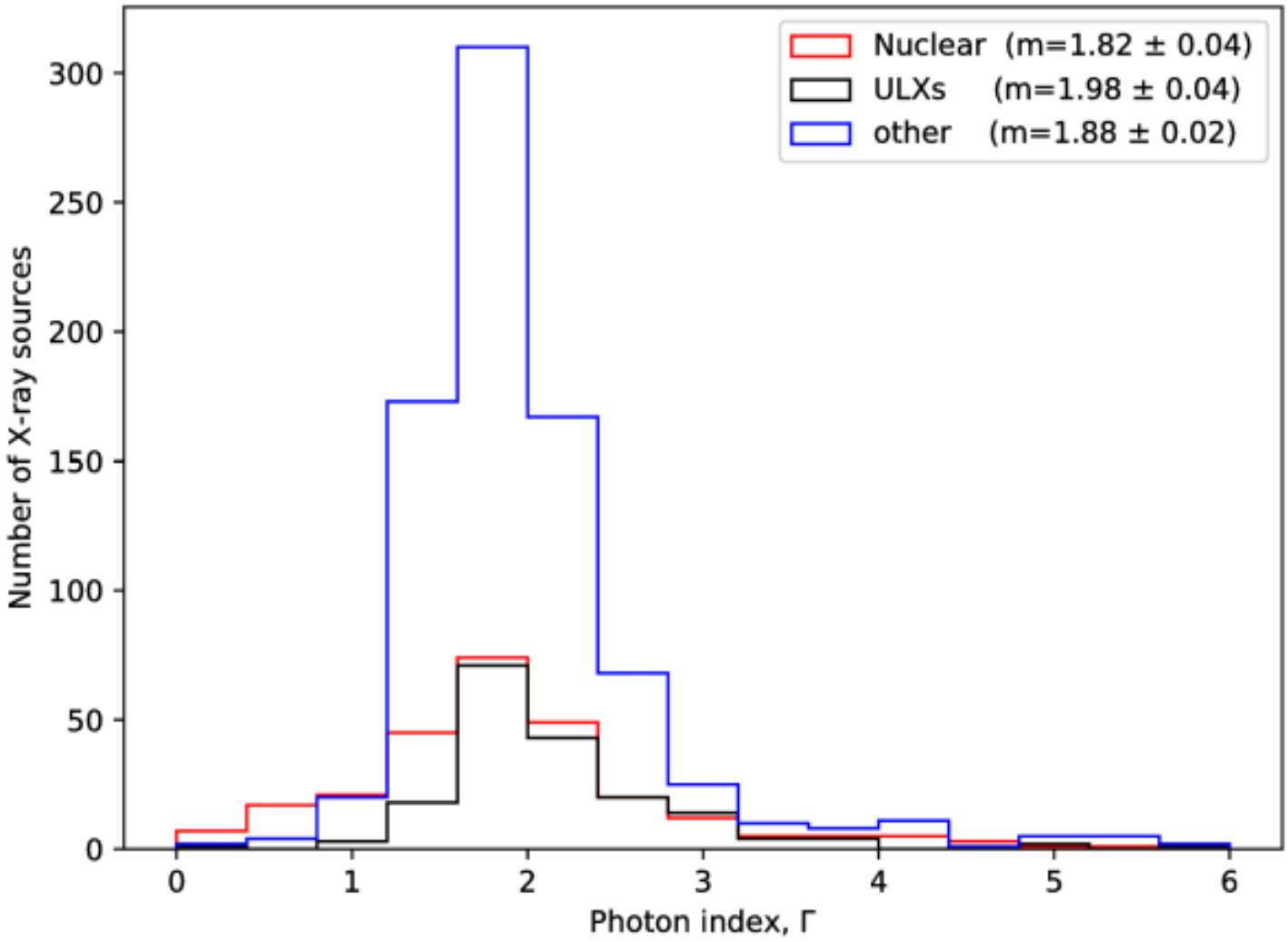
X-ray sources in our sample

- Preliminary results after cross-matching with CSC2 (Evans et al. 2010):
  - ~85% of the sources (~15000)
- For each source:
  - Luminosity assuming Galactic N_H, power-law model with $\Gamma=2$
  - Galactocentric distance (deprojected)
  - Identify off-center point-sources with $L_x > 10^{39}$ erg/s as ULXs
- For each galaxy:
  - Associated X-ray sources and number of observed ULXs
  - Bayesian model for subtracting foreground/background contamination using *ChaMP* log$N$–log$S$ (Kim et al. 2007)

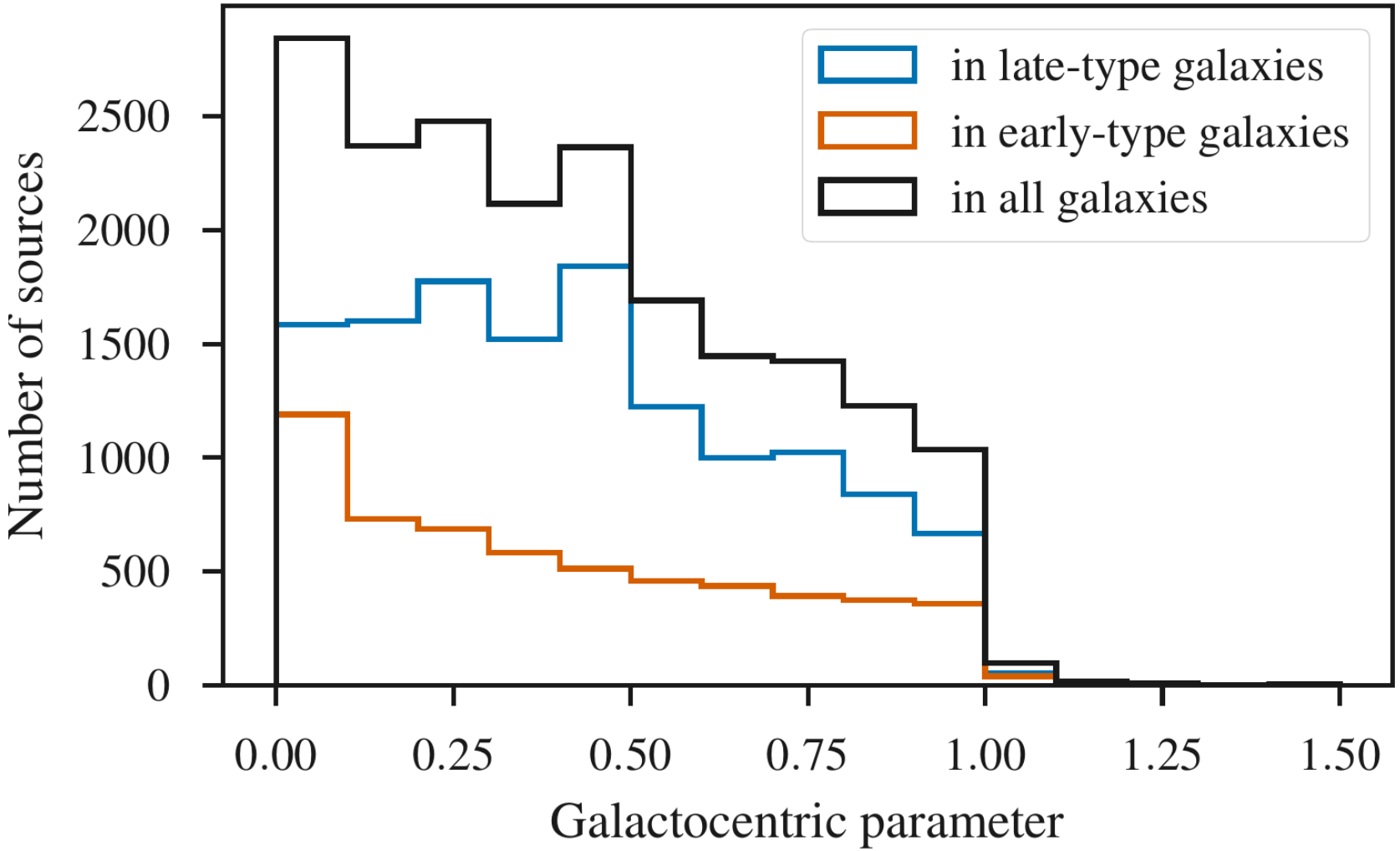
CSC 2.0 spectral fits: photon indices

using only fits with

$$\frac{1}{2} < \chi^2_\nu < 2$$

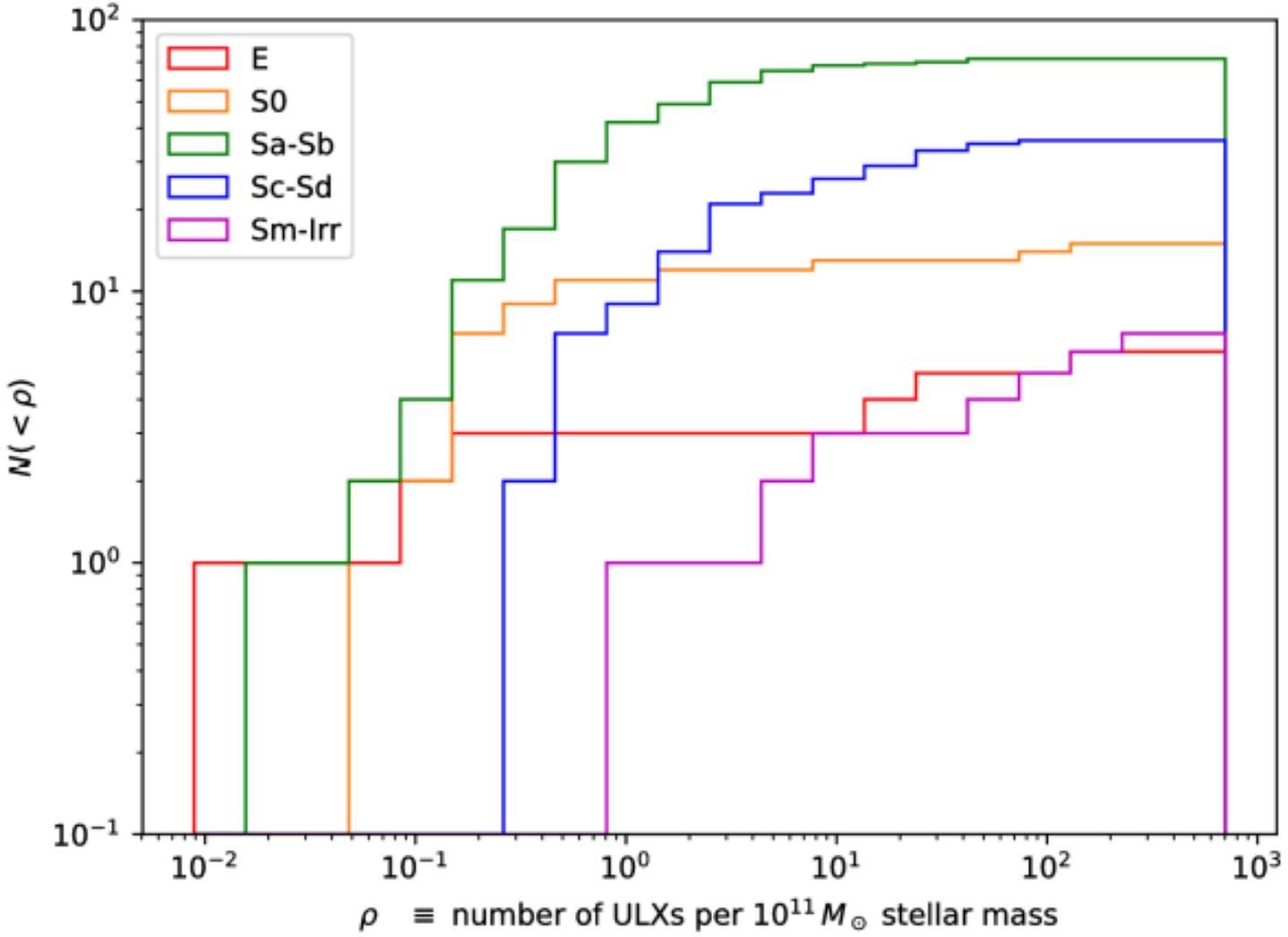


Radial distribution of sources



ULXs and morphological type

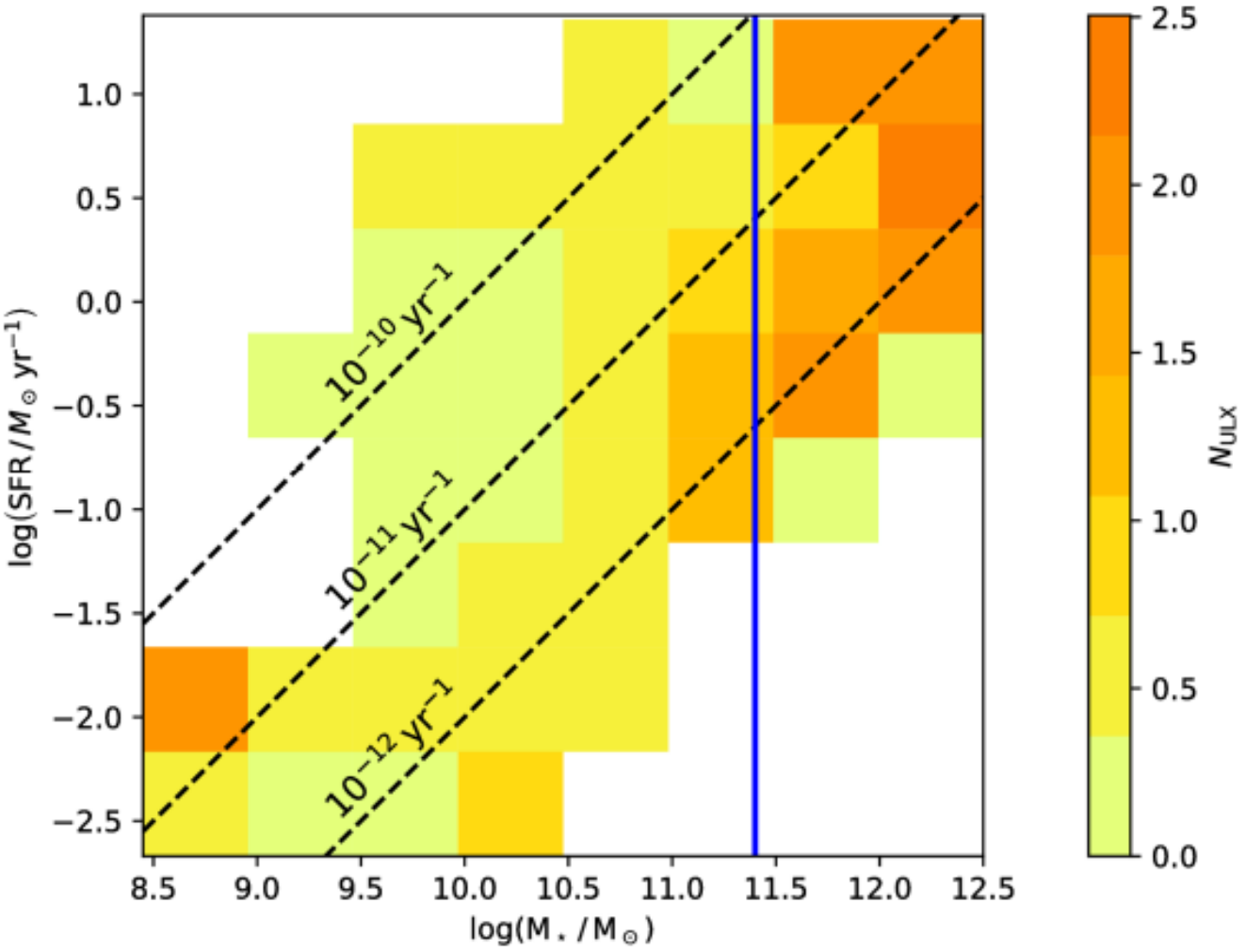
Cumulative distribution of *number of ULXs normalized by stellar mass* for different morphological classes



***Note**:*
D < 40 Mpc

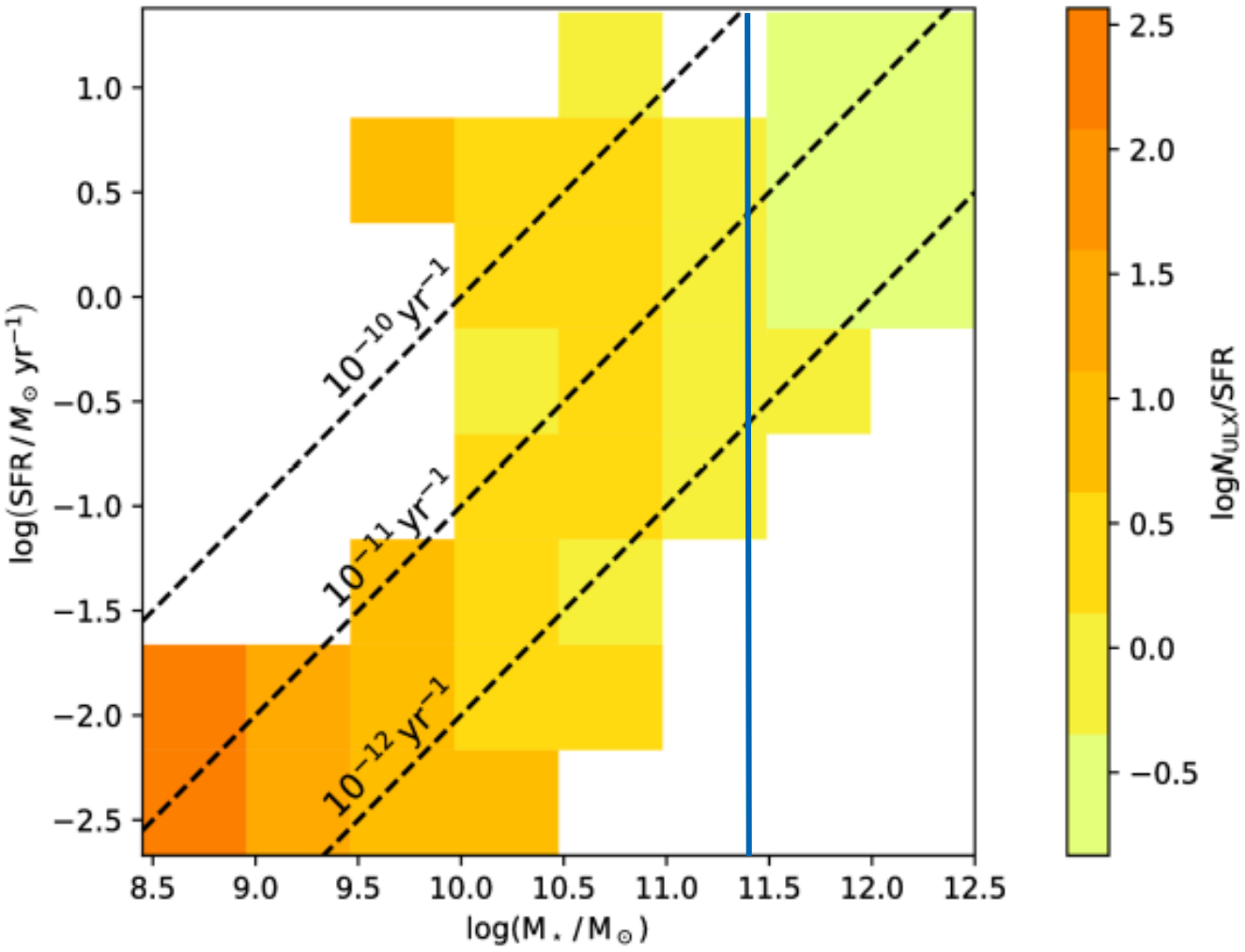
Number of ULXs vs. galaxy properties

- Binned galaxies with **D < 40 Mpc** → mean value
- Diagonal lines → **specific SFR**
- Blue vertical line → stellar mass for which contribution from **LMXBs** is important (using LF from Zhang et al. 2012)



Number of ULXs, normalized by SFR

- Binned galaxies with **D < 40 Mpc** → mean value
- Diagonal lines → **specific SFR**
- Blue vertical line → stellar mass for which contribution from **LMXBs** is important (using LF from Zhang et al. 2012)



Summary & future steps

- A **value-added master catalog** of galaxies:
  basis for many other extragalactic studies
- ULX population properties **vs** host properties
- Better statistics with **CSC 2.0**

...this is only the beginning!

- **Metallicity & age** effects
- **ULX luminosity functions**
- SFRs and stellar masses for the complete sample (SED fits)
- Source **confusion** corrections (Bayesian model)

Thank you